

MOTOR VEHICLE TECHNOLOGY: AUTOMATION OF DRIVING TASKS

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The World of Tomorrow exhibit at the World's Fair of 1938-39 envisioned a highway network that would whisk cars around New York City on a network of highways capable of guiding each to its intended destination automatically and in complete safety. All that was going to take place in the 1960s. We're obviously a bit behind schedule.

To a great extent, technology seems to follow the path of least resistance; what gets developed is what can be delivered, not necessarily what we may want or need. The last two decades have seen a considerable investment in the application of technology to devices capable of improving operation of motor vehicles. Grouped under the heading of "Intelligent Vehicle Systems" (IVS) various devices have been advanced to improve the safety and mobility of motor vehicles. Technology has developed to the point that experimental vehicles have been able to operate over experimental road segments without requiring anyone to drive them. In addition to making transportation more enjoyable, such hands-free operation offers the prospect of complete safety in what is presently the single greatest cause of accidental death and injury.

While keeping the vehicle on the road is an essential element of all driving, it is the simplest of driving tasks. It is quickly learned by beginners, and few accidents occur due to inability to stay within lane. Were there only one person on the road at a time, current technology would allow anyone to go anywhere with little effort and in total safety. But, most driving is done on roads filled with cars, trucks, buses, motorcycles and pedestrians, all going different place. The continual interaction among road users involves complexities of operation far beyond just keeping the car on the road. The processes involved in operating vehicles of all types have been classified as consisting of searching the environment for conditions requiring a response, identifying those conditions that require a response, deciding what response is needed, and executing the response. It is possible to design vehicle systems such that all the needed processes are automated, e.g., airport passenger shuttles. However, it is not necessary to achieve full automation in order to realize benefit.

Automation for Safety

There are two major ways in which automation can be of benefit in driving motor vehicles. One is by making it easier, to the point of not having to drive at all. The other is by making it safer, to the point of virtually eliminating the risk of an accident. This paper will be concerned solely with automation for safety. Each year in the U.S. more than 40 thousand drivers are killed and more than three million injured in motor vehicle accidents. Successful automation of driving tasks could help reduce the risk of death and injury. Knowing the accident rates associated with the

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different tasks would allow the development of automation technology to be directed along paths that will be most beneficial to the safety of the public.

The earliest and most comprehensive analysis of driving tasks and risk is the “Tri-Level” study of accident causes carried out by Treat et al. (1979) at Indiana University. The causes were identified through analysis of 13,568 police reports, 2,258 on-site investigations by project staff, and 420 in-depth analyses by specialists in various disciplines related to accident causation. What is particularly noteworthy is that the three sources of information gave very similar orders of magnitude to the numbers of accidents resulting from the various causes.

The most recent analysis of driving tasks and risk is that carried out by McKnight and McKnight (2000), based upon 2,138 detailed accident reports from California and Maryland. The analysis focused upon young drivers, the age groups whose accident rates are from three to nine times those of adults. However, the results parallel closely those obtained by Treat for the driver population at large and, concentrating solely on the driver’s role in accidents, allow a somewhat more detailed breakdown of task-related risks. The content of this paper is based heavily upon this analysis.

Car Following

Much of everyday driving takes place in a stream of traffic, one car following another. Among the most frequent accidents are those that occur when conditions force the lead vehicle to slow or stop and the second driver isn’t giving enough attention to traffic ahead or is following too closely to stop in time. Given the high incidence of rear end collisions, a device that can control following distances and respond to sudden changes could contribute greatly to the reduction of rear end collisions as well as making for less stressful driving.

Here is where automation has made one of its most significant contributions to actual driving and offers the greatest potential for accident prevention thus far. The last decade has witnessed the introduction of devices capable of measuring the distance and closing distance with vehicles ahead to identify dangerous conditions. The first devices simply sounded an alarm to alert drivers, who decided what to do about it, then did it. More recently Adaptive Cruise Control Systems (ACCS) have completed the automation process by controlling the speed in a manner than will maintain a safe following distance. These devices are currently available on automobiles from most manufacturers. An abundance of research has shown them to be effective in achieving separations that lead to smooth traffic flow and warning to drivers of closure rates that require more than just reducing acceleration. Research into the effect of ACC upon safety has recently been launched with controlled comparisons of accident rates for vehicles with and without these devices. As yet, no results seem to have entered the research literature. However, given the large numbers of accidents that arise from unsafe following, the potential for accident reduction is clearly great.

Search Ahead

The need to look well down the road for possible trouble is heavily emphasized in driving instruction. As frequent as car following accidents are those that occur when drivers fail to search the path ahead sufficiently to detect threats to safety in time to do something about them. Such threats include vehicles stopped in the path ahead, those slowing for something in their path or in preparation for a turn, as well as vehicles or pedestrians at the roadside that give some indication of possible entry to the path. The pattern also includes search for oncoming vehicles before starting a left turn; where a turn is delayed for some reason (e.g., pedestrians crossing the street to the left) drivers often commence the turn without one more check for oncoming vehicles in the lane to be crossed.

Radar detection devices warning of potential threats to the path ahead have long been employed in aircraft and ships. Their installation on the craft themselves as well as on land near areas of congestion, have allowed conflicts between ships to be detected at distances that permit courses to be changed in time to avoid collisions. Applying such collision avoidance technology to the highway will be greatly more challenging than applications to airways or waterways. Detecting relatively small position changes that represent possible threats, against the background of other forms of absolute and relative motion, and doing reliably enough to permit changes in speed or direction seems beyond present day technology. However, it may prove possible to at least provide a warning to alert a driver to a stopped vehicle or some other obstruction is detected in the path ahead. The warning might range from a non-intrusive visual or audible signal to a projected image of the obstruction.

Hazard Recognition

Somewhat related to the task of detecting clear threats to the path ahead is the ability to recognize what may become threats. The variety of hazardous conditions is almost limitless, including children playing near the road, a pedestrian near the curb looking the other way, or back-up lights on a parked car. Over years, drivers learn to recognize various hazards to the point that they react almost automatically, often even being unaware that they have done so. Skill in hazard recognition appears to be one of the developments that contribute to the steep drop in accident rate over the first few years of driving.

The prospects of automating the hazard recognition process to an appreciable degree seem even less promising than those of detecting what are clear threats to the path ahead. The ability of the human brain to recognize various visual patterns far outstrips that of current instrumentation. For example, people can recognize acquaintances despite the growth of beards, changes in hair styles, or added girth. Despite its potential role in preventing accidents, the task of recognizing subtle hazards in the traffic environment seems unlikely to enter the world of automation in the foreseeable future.

Crossing and Entering Traffic.

Crossing and entering a stream of traffic can be a complex and potentially dangerous task. Second in number to collisions with vehicles in the path ahead, are those that occur when drivers attempt to cross or enter a stream of traffic and are struck in the side. These occur mostly at intersections uncontrolled by lights and result from failure to look to the side before pulling out, looking but misjudging the size of the available gap in approaching traffic, or having an obstructed view and pulling out anyway. A not uncommon scenario is one in which a driver seeing no traffic from the left, waits until traffic from the right clears, and then pulls out without looking back to the left.

Means of reducing intersection collisions seem within the realm of present day technology. Devices mounted at intersections, measuring distance and approach speed of vehicles on main streets, can trigger a light or sound signal to warn the drivers on cross streets when it would be dangerous to pull out. Such site-specific measures would be expensive and most likely to merit installation primarily at high-accident locations.

An alternative to location-based systems would be signals emitted by vehicles capable of being received by other vehicles along the path ahead, such as those stopped at a cross street. When the distance and speed of an approaching vehicle were such to make an attempt to cross or enter the street a risky proposition, a warning would be received if the driver released to brake or started to move. At some point in the distant future, when the majority of vehicles are equipped with GPS, it might prove possible for vehicles to trade information in a manner that would alert their drivers to the presence of one another and issue warnings when it is unsafe to proceed.

With either site-located or vehicle-installed devices, achieving a high degree of implementation would be expensive. Yet, given the magnitude of the intersection problem, successful application of technology could yield a precipitous drop in the frequency of intersection collisions.

Speeding

When speed is mentioned as a contributor to highways accidents, much of the public thinks of impatient or aggressive drivers who would turn the highway into a race track. It is high speeds, producing large crash impacts, that lead to the fatalities which gain public attention. However, for the far greater number of non-fatal accidents the cause it is not so much high speeds as speeds that are simply too great for conditions of traffic, visibility, and road curvature or surface friction (rain, snow, ice). These conditions are generally accompanied by posted speed limits and the high accident rates suggest failure to accept the need for reduced speed.

Roadside devices have been used for several decades to measure vehicle speeds and display the results to motorists, an application of technology that unfortunately has been shown to have little effect in controlling speed, given the absence of visible enforcement. Speed control mechanisms, such as those employed in ACCS, provide a means of directly regulating speeds at various locations. In addition to measuring speeds of approaching vehicles, sensors could exert control by

sending signals to adaptive controls of approaching vehicles, yielding a benefit to safety, particularly at locations characterized by high accident rates. However, development of any device intended to give warnings or regulate speed must contend with the attempts by some drivers to override or defeat them.

Emergency Maneuvers

A study of last-second collision avoidance maneuvers was a part of the Indiana Tri-Level Study (Drahos and Treat, 1975). It revealed that up to a third of collisions could have been avoided by better braking, evasive steering or both. In the case of braking, a common contributor to collisions has been over-application of brakes, locking them and skidding out of control, a finding that led to a technological solution in the form of the Antilock Braking System (ABS). Paradoxically, the introduction of ABS was initially accompanied by an increase in rear-end collisions, an outcome attributed at last in part to having to unlearn controlled braking and overcoming the resistance to full application (which was accompanied by unnerving noises when ABS was first introduced). However, as drivers learn how to exploit the advantages of ABS, it will form part of technology's contribution to accident reduction.

There may still room for an evasive steering counterpart to ABS, one that would steer the vehicle into an unoccupied lane or a paved shoulder when a rear end collision is possible. However, with ACC controlling gaps in car following, the need for last-second lane changes should be greatly reduced. Its effect might well be assessed before any effort is applied to the development of automated evasive steering.

Traffic Controls

Relatively small numbers of accidents occur when drivers fail to respond properly to traffic controls. Although few drivers deliberately run red lights, more will enter the intersection too late and collide with vehicles or pedestrians who proceed on the green light. Accidents at red lights, and those involving vehicles that rolling through stop signs might be reduced if the drivers could be forced to stop long enough to take a good look at cross traffic. With braking control devices it might be possible to instrument high accident intersections with signals that would cause vehicles to come to a stop where required, particularly where it is apparent that the driver is not doing so. Once the vehicle stops, it would be allowed to proceed when traffic signals or cross-traffic permit.

Vehicle Control

An application of automation that has attracted a great deal of attention is that which allows drivers to drive without actually driving, that is, without operating the vehicle's controls. Some stretches of freeway and some vehicles have been experimentally instrumented to keep the vehicles in lane without driver control. Coupled with cruise control, automated steering would allow drivers to cover long stretches of highway without attention or effort; with adaptive cruise control they could do so in the presence of other traffic. On the long trips which take place on express highways, the lessening of boredom and fatigue is an obvious attraction.

The *safety* benefit of an automobile autopilot is less clear than its attractiveness to drivers. The express highways on which hands-off travel is most feasible see less than 10 percent of all accidents (although close to 20 percent of fatalities). As noted at the outset, the ability to control the vehicle is established early in driving and very few accidents result from skill deficits. Alcohol impairment and fatigue are the chief contributors to loss of control accidents. While safety benefits are welcome, they would appear to be residuals rather than the target of automation in control of the vehicle.

Summary

The automation of driving operations as a part of the Intelligent Vehicle System (IVS) will offer the prospect of reducing the burden placed upon drivers by certain tasks, particularly those that involve interaction with other road users. An obvious benefit would be a reduction in accidents that occur when drivers fail to perform those tasks adequately. Adaptive Cruise Control Systems (ACCS) appear capable of lowering the currently high incidence of rear end collisions by helping to maintain safe following distances and responding changes in the flow of traffic. ACCS coupled with embedded lane keeping devices could allow hands-off driving on specially designed controlled-access highways, minimizing the stress and strain of long trips.

When it comes to improving safety for many of the tasks associated with a high incidence of accidents, technology has a long way to go. Such tasks include (1) detecting and coping with threats to safety in the path ahead, (2) recognizing hazardous situations before they become threats, (3) warning drivers when it is dangerous to cross or enter traffic, and (4) preventing drivers from driving at speeds too fast for conditions, and (5) responding appropriately to traffic controls. Improvement in these areas will be far more difficult and costly to achieve than maintaining safe following distances and some many never take place. Still, the potential for reducing the death and injury associated with these tasks warrants a long term investigation of possible solutions together with a systematic examination of the benefits and costs of implementing them.

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